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INTEGRATION OF RENEWABLE ENERGIES IN THE DEVELOPMENT OF MODERN TRANSPORT INFRASTRUCTURE

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ABSTRACT

This paper deals with the investigation of the energy yield of renewable energy systems, specifically photovoltaic and wind turbines, for the prospective rising amount of e-cars. The aim of the paper is to determine the possible energy yield in comparison to the required energy of the vehicles on highways in Saxony.

1. INTRODUCTION

An extensive development is expected for the e-mobility sector in the future. The German car industry announced to launch vehicles with a pure electric drive in the next time. But the present infrastructure is not conforming to the requirements of the e-mobility and the usage of electric vehicles is strong limited. To entrench the e-cars the existing and newly constructed roads have to be adapted to the new requirements. Opportunities for loading the energy storage at filling stations or loading lanes have to be developed. Such a providing system could be supported by renewable energies along the highway.

2. POWER REQUIREMENT

For the investigation of the power requirement the required energy which is needed to get over the driving drag, was calculated. The driving drag of the vehicle depends on the speed, the route and the type of the vehicle. The focus for the sample route lies on a highway with three lanes for each direction and one hard shoulder. The dimension is given by the German rules of construction a highway [1]. The distance for the sample track is about 10 km, because the distance between the ramps is by an average of 8 km. For the further investigations sample routes with tracks of different gradients were selected (figure 1).

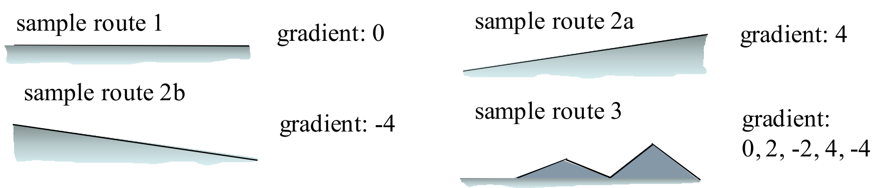
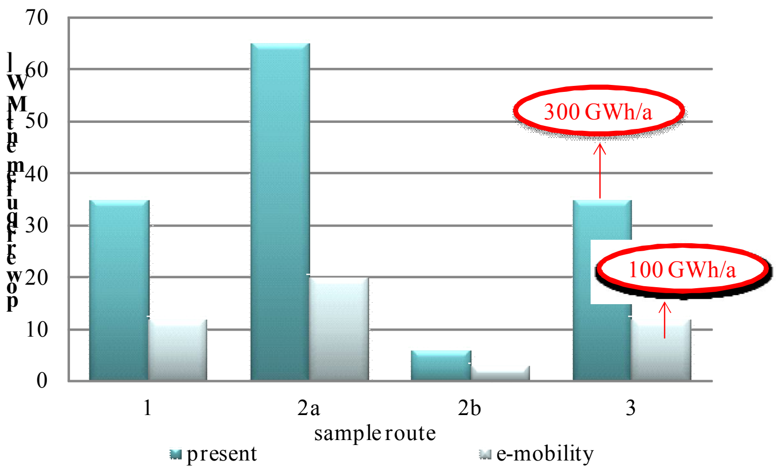


Figure 1 – Profiles of the sample routes

Two scenarios were simulated. The first one represents the average of the power requirement of the present vehicle distribution and the second one represents the power requirement at 100% e-cars (figure 3). The sample vehicles of the first case are VW Polo, VW Golf, VW Passat and Porsche Panamera. In the second case the representative vehicles are Twike, Mitsubishi iMiev and VW E-Golf. The percentage of the sample vehicles was equated at 100%. The efficiency for the vehicle is the average of the efficiency of the sample cars [2]. The distances between the cars were calculated with the half of the speedometer-rule.



present:

- cars with conventional drive and few cars with electric drive (only VW E-Golf)

e-mobility:

- 100% electric cars

efficiency of the cars:

- $\eta_{\text{convential (diesel)}}$: 0,28
- $\eta_{\text{e-car}}$: 0,84

Figure 2 – Average power requirement for all sample vehicles (10 km, 130 km/h, one driving direction)

The last sample route with the combined tracks is the representative one. In one year the required energy for the present vehicle distribution and for one driving direction is about 300 GWh. In comparison the annual energy consumption is about 100 GWh by a percentage of 100% e-cars. Under the assumption of smaller e-cars and lower driving speeds a further bisection of the power requirement can be expected.

3. FIRST PRESUMPTION FOR THE ENERGY YIELD BY RENEWABLE ENERGIES

The unused space of the highway offers much area to install renewable energy plants. Photovoltaic systems can be installed on the median strip, on the bank, on the noise barrier and on the open space next to the highway. In addition the open space next to the highway (wide: 40 m, minus area of traffic security, tunnels, bridges, and noise protection dams) offers the possibility to install large wind turbines. At first without consideration the land use plan for the area next to the highway, e. g.: development, agriculture. Furthermore small wind turbines, which could use the slipstream of the trucks, should be considered.

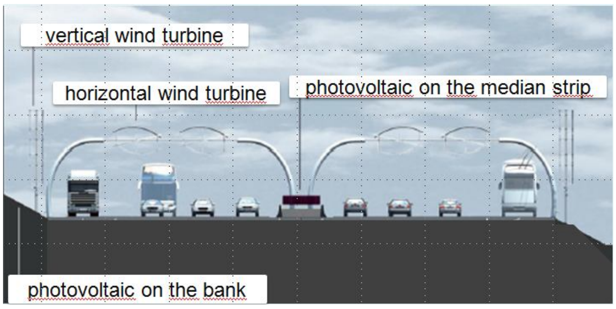
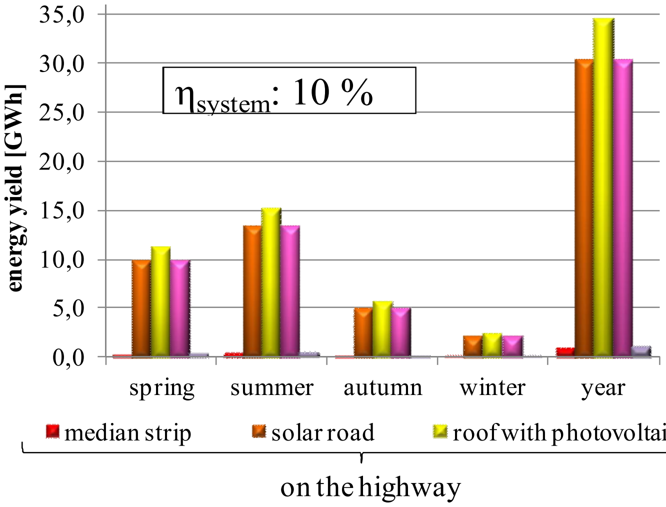


Figure 3 – Renewable energies along the highway [3]

Most of the wind turbines, which were built in the present time, are with a rising trend of the power range. So the wind turbine Vestas V112 (power: 3 MW, rotor diameter: 112 m) was selected as a representative. The second wind turbine (power: 4,5 MW, rotor diameter: 136 m) was selected because of the good low wind characteristic. Large wind turbines can be only built on one side along the highway. The distance between each turbine is about 500 or 700 m. This corresponds to 20 or 14 units (depends on the rotor diameter). The results of the wind distribution, created with the data of the test reference year of the German weather service (DWD) [4], were placed over the published power curves [5], [6] of the selected wind turbines The energy yield is almost constant about the year. For the Vestas wind turbine the energy yield is about 220 GWh/a and for the Gamesa wind turbine the energy yield is about 280 GWh/a.

An efficiency of 10% was accepted for calculation the energy yield of the photovoltaic systems. The table next to the chart of figure 4 shows the area of the different installing places, the tilt of the panels and which percentage of the area can be used. The rate of the noise barrier bases on the study of the Federal Ministry of Transport, Building and Urban Development [7] and was transferred to the amount of the highway in Saxony. The global radiation was given by the data of the test reference year of the DWD (zone 9).



	area [m²]	tilt [°]	usable part [%]
[illegible]	[illegible]	[illegible]	[illegible]
roof	330.000	0	100
[illegible]	[illegible]	[illegible]	[illegible]
open space	652.400	35	37
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Figure 4 – Energy yield of the photovoltaic systems

Figure 4 shows the highest possible yield which is generated with photovoltaic panels on a roof above the highway. The photovoltaic systems on the open space provide the highest yield on the area next to the highway. The calculated energy yield of the median strip and the noise barrier only add a small part to the total yield.

For comparison the energy yield with the energy consumption two case studies are selected. The first case represents the best case in which the maximum energy yield is generated. The second one represents a realistic case in which only 20 % of the wind tur-bines and 50 % of the photo-voltaic systems can be installed on the area next to the highway.

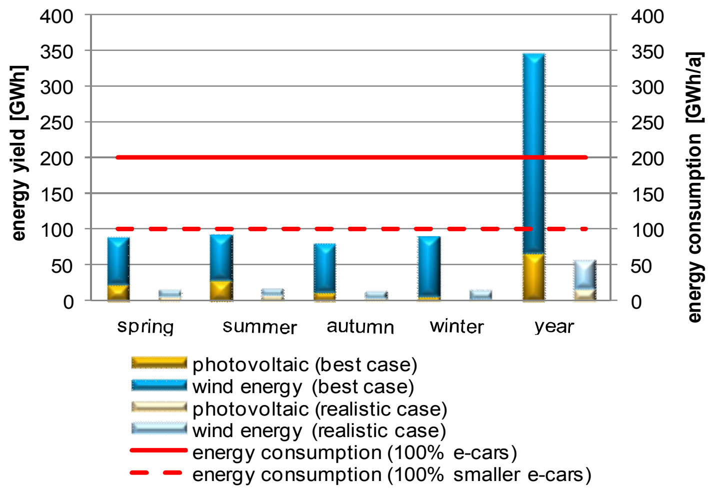


Figure 5 – Comparison of the required energy with the total yield of renewable energy systems

4. CONCLUSIONS

For a route with combined tracks and with a speed of 130 km/h the energy consumption (peak load) by the average of the vehicle distribution of the present days is about 600 MWh/a. At 100% e-mobility the energy consumption can be reduced to approximately 1/3. In comparison the maximum energy yield of renewable energies along the highway is about 350 GWh/a. But under realistic conditions only about 30% of this energy amount could be covered and the main part of the produced energy is supplied by the large wind turbines. In comparison if the smaller e-cars require only the half energy, the renewable energy systems will provide over the half of the required energy.

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